AUSTRALIAN PHYSIOTHERAPY ORIGINAL ARTICLE

Responses to mechanical stimulation of the upper limb in painful cervical radiculopathy

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Clinical and electromyographic (EMG) responses to non-noxious mechanical stimuli were studied in four patients with painful cervical radiculopathy, and in two control subjects. In the symptomatic arm(s), palpation over one or more nerve trunks was painful and accompanied by EMG activity, whereas palpation of adjacent soft tissues was painless and unaccompanied by EMG activity. Electromyographic activity was widespread in three patients when myotatic reflexes were elicited in the symptomatic arm(s). In asymptomatic arms of patients and controls, EMG responses to the myotatic reflexes were more localised. Allodynic nerve trunks in cervical radiculopathy appear to be afferent correlates of central sensitisation; the accompanying EMG activity may represent a motor correlate of this same process.

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Tenderness, or more properly mechanical allodynia (International Association for the Study of Pain Subcommittee on Taxonomy 1988), of muscles in the neck, upper back, shoulder girdle and arm is said to be a frequent finding in patients with cervical radicular pain (Elliott and Kremer 1945). Some authors have noted that when these same areas are palpated, pain (with or without paraesthesiae) can be referred into other tissues (Travell and Rinzler 1952). These "trigger" areas or points were originally thought to represent irritable foci within the muscles (Elliott 1944b) which could become self-perpetuating and an important additional cause of painful disability (Travell 1976). However, in the clinical context of painful radiculopathies or neuropathies, nerve trunks themselves can exhibit mechanical allodynia, often accompanied by referred pain phenomena (Asbury and Fields 1984). The potential for clinical diagnostic confusion, and ineffective or even harmful physical treatment, is considerable. It is therefore appropriate to explore the possible relationship between pain of peripheral nerve origin and changes within the motor system from both the clinical and neurophysiological aspects.

Over the last decade, physiotherapists have pioneered clinical examination techniques designed to assess the mechanosensitivity of the major nerve trunks related to the upper limb. Whereas the various constituent manoeuvres of what have become known as upper limb tension tests depend upon knowledge of the anatomy and biomechanics of peripheral neural tissues, their clinical interpretation is dependent upon both the subjective report of the patient and the judgment of the examiner (Butler 1991). Whilst reliance upon subjective responses for clinical diagnosis is not an uncommon situation in musculoskeletal medicine, a valid criticism of upper limb tension tests is that many non-neural structures (including muscle) could potentially contribute to, or be responsible for, a painful response. Another criticism of these tests is that they increase tension within the entire extent of the neural tissues which span the neck and hand, making it difficult to localise the anatomical origin of painful neural pathology. For these reasons nerve trunk palpation, a time-honoured part of the neurological examination (Nothnagel 1877), may be a simpler and more specific means of assessing mechanosensitivity of individual nerve trunks.

In the normal situation, palpation of nerve trunks is painless. However, the pathophysiology of mechanical allodynia of nerve trunks is poorly understood, as is the relationship between this phenomenon and underlying peripheral neural damage

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and dysfunction. In the following sections, the state of current knowledge in this important area of musculoskeletal medicine is briefly reviewed, mainly in relation to the clinical presentation of painful cervical radiculopathy.

Nerve trunk pain

The connective tissues of peripheral nerve trunks are known to be innervated by nociceptive sensory fibres (peptidergic fibres with terminals containing substance P and calcitonin gene-related peptide, and other algogenic chemicals) and are therefore potential sites of a local injury response (Zochodne 1993). In addition, these tissues contain encapsulated nerve endings (Thomas et al 1993) which could normally function as mechanoreceptors (Iggo 1985). Although nerve trunk pain has been attributed to increased activity in mechanically or chemically sensitised nociceptors within the nerve sheath (Asbury and Fields 1984), this mechanism does not explain mechanical allodynia of structurally normal nerve trunks, nor accompanying pain and allodynia referred into other deep tissues. In this case, non-nociceptive input from the presumed nerve trunk mechanoreceptors is being processed abnormally within the central nervous system, in all probability the result of a sustained afferent nociceptive barrage from the site of nerve damage (Sugimoto et al 1989), a pathophysiological process termed central sensitisation (Woolf 1991).

Mechanical allodynia of nerve trunks in radiculopathy

According to Dyck (1987), the entire extent of the sciatic nerve trunk is invariably allodynic when a lumbo-sacral nerve root is traumatised. By contrast, Spurling and Segerberg (1953) stated that mechanical allodynia of upper limb nerve trunks is not usually found in association with lesions of the cervical spine, this phenomenon being more typically a feature of brachial neuritis. However many cases of what was once termed brachial neuritis were in fact painful subacute or chronic cervical radiculopathies (Wilkinson 1971). Furthermore, although mechanical allodynia of nerve trunks is said to be an important finding in patients with painful cervical radicular pathology due to cervical spondylosis (Russell 1956), no studies have been undertaken to determine its frequency, nor is this clinical finding even mentioned in a recent review of cervical radiculopathy (Radhakrishnan et al 1994).

Table 1.
Clinical data on four patients with cervical radiculopathy.

Case no.	Age	Sex	Occupation	Level of Radiculopathy	Cause	Duration of symptoms (weeks)
1	41	M	Accountant	C6	injury	32
2	52	F	Clerk	C7	injury	7
3	58	M	Pharmacist	C5 (7)	injury	16
4	59	F	Nursing assistant	C8	-	8

Reflex motor activity in radiculopathy

Central changes known to occur in response to either ongoing nociception or ectopic impulse generation include spontaneous firing and enlarged receptive fields of nociceptive dorsal horn neurones (Dubner 1991). These, and perhaps other, central changes can affect the function of spinal motor neurons, rendering them hyperexcitable (Woolf 1983). In animal experimental models, prolonged facilitation of the flexor reflex can be induced by ectopic C-afferent fibre input arising from damaged or dysfunctional peripheral nerves (Woolf and Wall 1986).

Spinal reflexes such as the stretch reflex can be used to assess the general excitability of the spinal cord, as well as the integrity of both the afferent and motor connections. The myotatic reflex (tendon jerk) is the clinical examination technique commonly used to test the integrity of the stretch reflex arc and to assess the activity of α- (and indirectly γ-) motor neurones at any level of the spinal cord (McLeod et al 1995).

The stretch reflex has been studied in the clinical contexts of spasticity (Lance and Gail 1965) and dystonia (Rothwell et al 1988) but has not been used to assess spinal excitability in painful cervical radiculopathy where the presence of segmentally-related hyperexcitable spinal motor neurons could provide a window through which reflex motor responses to non-noxious stimuli administered to the painful upper limb can be examined.

Aim of this study

In this study, clinical and electromyographic (EMG) responses were recorded in patients with painful cervical radiculopathy and in control subjects during palpation over major nerve trunks, adjacent muscles and other soft tissues, and also during elicitation of myotatic reflexes. It was hypothesised that in these patients, a state of spinal hyperexcitability exists at the level of radicular damage which will be manifested clinically by increased mechanosensitivity of anatomically related peripheral nerve trunks, and electromyographically by an increase in reflexly-induced motor activity.

Method

Subjects

The subjects of the study were four patients who presented to the practice of one of the authors, complaining of cervicobrachial pain, and in whom there was both clinical and other supporting evidence for a diagnosis of cervical radiculopathy (Table 1). In no case was compensation or litigation for injury an issue. Two asymptomatic volunteers (a 35-year-old male and a 51-year-old female) were used as normal control subjects; neither had any prior knowledge of the purpose or details of the study.

Patient 1

History: A 41-year-old male accountant with a long history of recurring left sided cervical pain presented with a moderately severe left cervicobrachial pain syndrome which developed soon after dragging his boat from the water, and was exacerbated a month later when he sustained a minor neck injury in a swimming pool accident. He complained of deep aching pain in his neck, left shoulder and upper arm on the outer aspect, which radiated to the elbow, particularly when reaching upwards and outwards with the left arm. He also complained of tingling in the middle and ring fingers and over the dorsum of his left hand.

Clinical examination: Active cervical extension and right lateral flexion were both painful and limited. Upper limb tension testing reproduced his left shoulder and upper arm pain. The shoulder joint complex was clinically normal. Apart from diminished sensation within the C6 dermatomal distribution, there was no other evidence of neurological deficit in his painful arm.

Investigations: Cervical radiology showed a slight loss of height of the C4-5 and C5-6 intervertebral discs. A CT scan of the cervical spine showed mild narrowing of the left C5-6 neural foramen by uncovertebral osteophytes. On needle electromyographic examination performed by a neurologist, there was both increased insertional activity and evidence of active and chronic partial denervation in the C6 myotome consistent with a left C6 radiculopathy. Nerve conduction in this limb was normal.

Patient 2

History: A 52-year-old female part-time clerical worker felt a "tearing" pain in her right medial scapular region when lifting a heavy suitcase in her right hand. Within days of this episode, she also complained of severe neck pain and bouts of paraesthesia radiating down the right arm, mainly into the index and middle fingers. She gave a history of a minor neck injury when aged 29 years, which was followed by acute neck pain and right arm numbness lasting three days or so. Episodic attacks of neck, right upper arm and lateral elbow pain had occurred over the ensuing years.

Clinical examination: The range of cervical spinal movement was reduced both on lateral flexion to the left and on rotation to the right. The foraminal compression test to the right was positive with numbness developing over the dorsal aspect of the forearm and wrist. There was mild weakness in the right triceps, pronator teres and extensor indicis. The right biceps and triceps reflexes were reduced, as was sensation over the right C7 dermatome.

Investigations: On CT scan of the cervical spine a broad-based, right of centre, disc protrusion was reported at C6-7, which extended out into the right C7 neural foramen where there was loss of perineural fat radiolucency. At both C4-5 and C5-6 levels, broad-based degenerative posterior osteophytic lipping was present, causing narrowing of the relevant neural foramina. Electrodiagnostic testing performed by a neurologist within two weeks of onset of symptoms was within normal limits.

Patient 3

History: A 58-year-old retired male pharmacist presented with severe left shoulder pain and restriction of shoulder movement of three months duration which had first been noted in the immediate post-operative period following abdominal surgery for repair of an incisional hernia and division of intra-abdominal adhesions. He complained also of milder pain in his right shoulder. He could not recall a previous history of neck pain but some three months prior to this operation, he had fallen injuring his left shoulder and experienced severe pain and difficulty in using his left arm for some two weeks afterwards.

Clinical examination : The principal findings were painful restriction of left shoulder movements in all directions, and reduced cervical extension and both lateral flexion and rotation to the left. These movements reproduced his left shoulder pain, as did upper limb tension testing. There was gross wasting of the left deltoid muscle, diminution of the left supinator and biceps reflexes, and hypoaesthesia over the C5 dermatome. In the right arm, all shoulder movements were mildly restricted and painful, but there were no abnormal neurological signs.

Investigations: Needle EMG examination performed by a neurologist revealed findings consistent with a recent left C5 radiculopathy, as well as with a chronic or old partial left C7 radiculopathy. In addition, there was evidence of an electrophysiologically mild to moderate left median neuropathy at the wrist. The right upper limb was not tested. Radiological examination of the left shoulder was normal. Cervical spinal degenerative changes were present bilaterally between C4 and C7, with narrowing of the neural foramina due to prominent osteophyte formation. A CT scan of the cervical spine performed in conjunction with a myelogram showed a large foraminal osteophyte narrowing the left nerve canal at C6-7 and blunting the origin of the C7 nerve root, but no changes were seen at the C5-6 intervertebral disc level. Thus these investigations did not reveal an anatomical lesion within the cervical spine responsible for the C5 radiculopathy.

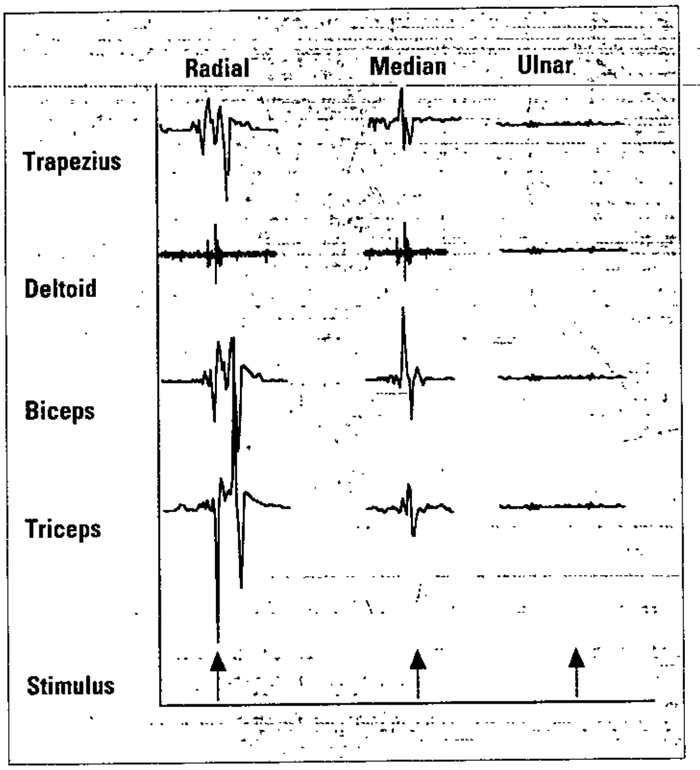

Figure 1.
Electromyographic activity recorded in the left trapezius, deltoid, biceps and triceps brachii muscles during palpation of the radial, median and ulnar nerve trunks in the symptomatic (left) arm of Patient 1.

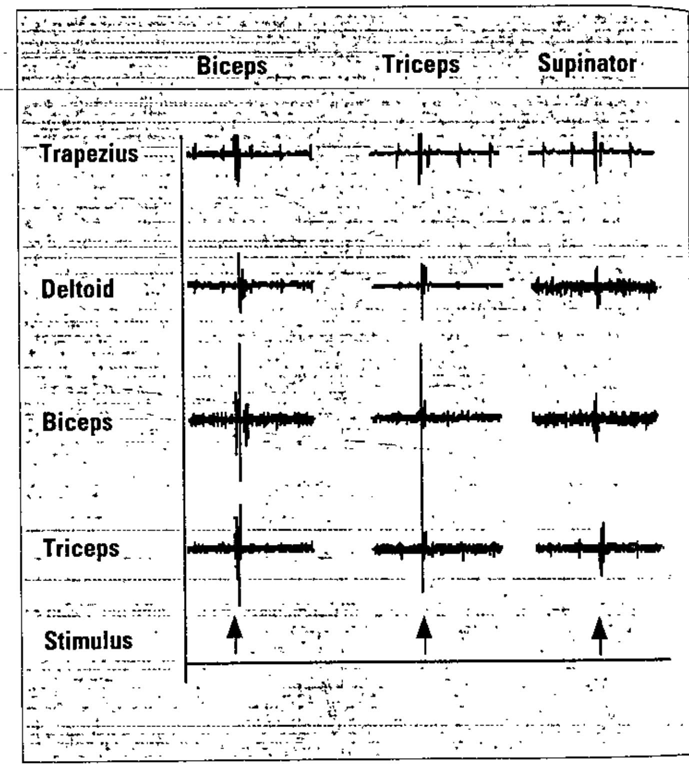

Figure 2.
Electromyographic activity recorded in the trapezius, deltoid, biceps and triceps brachii muscles during elicitation of the ipsilateral biceps, triceps and supinator myotatic reflexes in the symptomatic (left) arm of Patient 1 (note background recording of heart rate).

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Patient 4

History : A 59-year-old female nursing assistant presented with a three week history of right cervicobrachial pain, which was similar to that with which she had presented to one of the authors five years previously. Her pain was felt in the scapular region, extending into the posterior aspect of the upper arm, upper portion of the forearm on the radial aspect, and into the ulnar two digits of the right hand. Transient paraesthesiae had also been noted in the hand.

Clinical examination : Cervical movements to the right were painful and restricted. Upper limb tension testing was positive for her right upper limb pain. On neurological examination, the right triceps reflex was diminished, and there was mild weakness of the triceps muscle.

Investigations : A cervical myelogram demonstrated a prominent anterior impression upon the thecal sac at the level of the C6-7 disc space, and underfilling of the left C7 nerve root axillary pouch with normal filling of the remaining axillary pouches. A post-myelogram CT scan showed a large left-sided postero-lateral osteophyte at C6-7 causing an anterior impression upon the thecal sac, effacement of the anterior subarachnoid space, a little rotation of the cord and underfilling of the left C7 nerve root sleeve. The presence of an associated right postero-lateral disc protrusion was also suspected at C6-7. The findings on needle electromyography performed by a neurologist were those of a subacute partial right C8 radiculopathy, or possibly of a partial lower trunk brachial plexopathy.

Instrument and procedures

Surface EMG is a non-invasive technique and is generally acceptable for the purposes of a study such as this (Caldwell and Villarreal 1992). In each subject, the impedance of the skin overlying the muscles to be tested was reduced to less than 1000 ohms by shaving off hair, washing the skin with alcohol and, if necessary, lightly abrading it (Winter 1991). Bipolar surface electrodes were then placed longitudinally 2cm apart over the mid-belly of the upper trapezius (C3-4), deltoid (C5-6), biceps (C5-6) and triceps (C7-8) muscles on the side of the arm being tested. A ground electrode was placed over the acromion process superiorly. Immediately before and during the application of each stimulus as outlined below, 8s of raw EMG signal were amplified at a constant gain, band pass filtered at

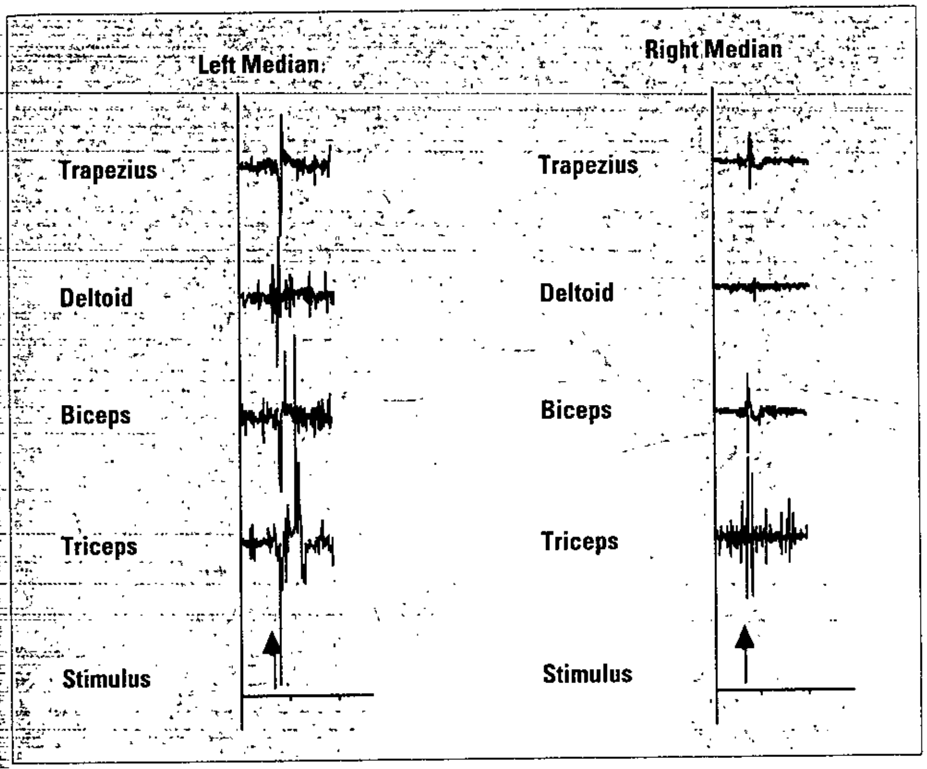

Figure 3.
Electromyographic activity recorded in the trapezius, deltoid, biceps and triceps brachii muscles during palpation of the respective ipsilateral median nerve trunk in Patient 3 (note poor relaxation in muscles of left arm).

8 Hz and 800 Hz by a Medelec eight channel EMG unit and then recorded and stored on a Macintosh computer at a sampling rate of 2000 Hz (Winter 1991).

Prior to testing, subjects were asked to report any pain felt during each of the test procedures and to place their arms in the position of maximal comfort. With the subject relaxed and recumbent, the four muscles were simultaneously monitored for EMG activity at baseline, and then when the examiner (TH) attempted to elicit the ipsilateral biceps, triceps and supinator myotatic reflexes without using reinforcement. EMG activity was again monitored when the examiner palpated gently over the ipsilateral radial, median and ulnar nerve trunks. Palpation over the ulnar nerve trunk was performed behind the medial epicondyle in the ulnar groove, over the radial nerve trunk in the postero-lateral upper arm a few centimetres below the deltoid muscle insertion, and over the median nerve trunk as it lies medial to the brachial artery under the belly of the biceps (Williams et al 1989). The technique of nerve trunk palpation consisted of gently drawing a thumb or finger across the nerve (Butler 1991). Finally, following on the recommendations of Elliott (1944a), pain responses were noted, and EMG recordings obtained, during gentle palpation of the skin and subcutaneous tissues overlying each putatively allodynic nerve trunk and, in the case of the median and radial nerve trunks, during palpation of the bellies of the adjacent biceps and triceps muscles respectively.

Analysis

For each test situation, EMG activity in response to a stimulus was rated as being either present or absent in each of the muscles sampled. In a pain-free upper limb, it was anticipated that there would be no EMG activity in response to any of the palpatory stimuli. The situation regarding the myotatic reflexes is more complex. In normal subjects, myotatic reflex responses are symmetrical. The pattern of normal response can include: no activity (where reinforcement is necessary to elicit the reflex); activity recorded only, or predominantly, in the agonist muscle(s) (Myklebust et al 1982); activity recorded in both agonist and antagonist muscles (Kudina 1980); and spread of activity into distant muscles (Lance and Gail 1965).

Results

Normal subjects

There were no complaints of pain and no EMG activity on palpation over nerve trunks in either of the normal subjects. In the male subject, EMG activity recorded when each of the myotatic reflexes were elicited on either side was confined to single (agonist) muscles. In the female subject, EMG activity was recorded in the biceps muscle during elicitation of the respective biceps reflex. No activity was recorded during attempts to elicit each of the triceps and the supinator reflexes. However, these reflexes could be elicited with reinforcement, indicating that the respective stretch reflex arcs were intact.

Patient 1

Testing was carried out some eight months after the initial injury. A simultaneous burst of activity was recorded in all muscles sampled on the painful (left) side when palpation was performed over the radial and the median nerve trunks (Fig. 1), both of which sites were allodynic, and when the myotatic reflexes were elicited (without producing pain) (Fig. 2). The other stimuli did not result in EMG activity, nor were they painful. EMG activity was localised to single agonist muscles when each reflex was elicited in the opposite (pain free) arm. No

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pain nor EMG activity occurred in response to palpatory stimuli in this arm.

Patient 2

Testing was performed seven weeks after the onset of symptoms. On palpation over the right radial nerve trunk, a painful response was noted, and EMG activity was recorded in all muscles studied. Palpation over the other nerve trunks in this arm did not produce pain, nor was EMG activity recorded. There was no EMG activity in response to the other palpatory stimuli in the painful arm. In the asymptomatic left arm, palpation over nerve trunks did not result in EMG activity. On eliciting the myotatic reflexes in the painful arm, simultaneous activity developed in the biceps and triceps muscles with the biceps reflex, but no activity accompanied the other reflexes. In the asymptomatic arm, activity in the biceps muscle accompanied the biceps and supinator reflexes, but none was recorded during the attempt to elicit the triceps reflex.

Patient 3

Testing was carried out 16 weeks after the onset of the shoulder pain. Pain resulted from palpation over both median nerve trunks, and EMG activity was recorded in all muscles on the ipsilateral side when each of these nerve trunks was palpated (Fig. 3). Neither pain nor EMG activity was present when the other nerve trunks of either arm were palpated. Widespread EMG activity was present on both sides when the biceps reflex was elicited, and on the right side when the triceps reflex was elicited. In the left arm, activity was present in biceps and triceps when the triceps reflex was elicited, but no activity was recorded during the attempt to elicit the supinator reflex. No activity was seen in either arm in response to the other palpatory stimuli.

Patient 4

Testing was performed eight weeks after onset of pain. On the symptomatic (right) side, pain together with widespread EMG activity was recorded on palpation over the median nerve trunk. However, pain unaccompanied by EMG activity was also noted on palpation over the ulnar and radial nerve trunks. Widespread EMG activity was recorded during elicitation of the biceps reflex. A more localised response accompanied the supinator reflex, but none accompanied the attempt to elicit the triceps reflex. No EMG activity was seen in response to the other stimuli. On the asymptomatic (left) side, EMG activity was recorded in single agonist muscles when the biceps and triceps reflexes were elicited; but none was recorded during the attempt to elicit the supinator reflex. No EMG activity was seen in response to the other palpatory stimuli.

Table 2. Electromyographic responses to nerve trunk palpation in four patients with cervical radiculopathy. The number of muscles in which a response was recorded is shown for each arm (max. = 4).

Nerve	Patient 1		Patient 2		Patient 3		Patient 4	
	R	L*	R*	L	R*	L*	R*	L
Median	0	4#	0	0	4#	4#	3#	0
Radial	0	4#	3#	0	0	0	0#	0
Ulnar	0	0	0	0	0	0	0#	0

R=right, L=left
* - symptomatic arm(s)
\# - hyperalgesic nerve trunks

Summary of responses

Mechanical allodynia, which appeared to derive from major nerve trunks, was present in each painful upper limb. The median nerve trunk was putatively involved in each patient, the radial nerve trunk in each of those with either a C6, C7, or C8 radiculopathy, and the ulnar nerve trunk only in the patient with a C8 radiculopathy.

As shown in Table 2, the pattern of EMG activity in response to palpation over some or all of the putatively allodynic nerve trunks in each patient is consistent with hyperexcitability of motor units over a number of spinal segments. A similar pattern of widespread EMG activity in response to elicitation of myotatic reflexes in the symptomatic upper limbs found in Patients 1, 3 and 4, lends support to this interpretation of the palpatory findings (Table 3).

Discussion

Diagnosis

Each patient presented with positive sensory symptoms and clinical examination findings consistent with cervical radiculopathy. In no patient was there clinical evidence of cervical myelopathy. In the absence of clinical evidence of a right cervical radiculopathy, the mechanical allodynia overlying the right median nerve trunk in Patient 3 appears to be an example of the poorly understood phenomenon described in the last century as neuritis sympathica (Nothnagel 1877).

The clinical presentation of Patient 3 was consistent with either shoulder pathology (tendonitis or adhesive capsulitis) secondary to pain referred from within the cervical spine, or dual cervical and left shoulder pathology. There was no clinical evidence of any musculoskeletal abnormality in the upper limbs of the other patients.

Table 3.
Electromyographic responses to myotatic reflexes in four patients with cervical radiculopathy. The number of muscles in which a response was recorded is shown for each arm (max. = 4).

Reflex	Patient 1		Patient 2		Patient 3		Patient 4	
	R	L*	R*	L	R*	L*	R*	L
Biceps	1	4	2	1	4	3	3	2
Triceps	1	4	0	0	4	2	0	1
Supinator	1	4	0	1	2	0	2	0

R=right, L=left
* - symptomatic arm(s)

In Patients 1, 3 and 4, needle EMG findings were characteristic of cervical radiculopathy. Although positive EMG findings were not present in Patient 2, testing may have been performed too early for the development of changes of denervation. Nevertheless, this patient's clinical presentation and the radiological findings supported a diagnosis of C7 radiculopathy.

Elicitation of myotatic reflexes

Radiation of reflex activity to muscles distant from the segmental level being examined can be seen in normal subjects with brisk tendon reflexes (Lance and Gail 1965), but is more prominent in patients with dystonia (Rothwell and Obeso 1987) or spasticity (McLeod et al 1995). This response has been attributed to hyperexcitability of α-motor neurons in the spinal cord and to local mechanical spread of a vibration wave from bone to muscle, stimulating excitable muscle spindles in its path (McLeod et al 1995).

The more widespread radiation of myotatic reflex activity on the side of the painful arms of the subjects in this study suggests that unilateral (bilateral in Patient 3) pathophysiological changes have occurred within components of the stretch reflex. Such changes could include increased excitability of α-motor neurons, the loss of reciprocal inhibition of the α-motor neurons over a number of cervical spinal segments, and increased excitability of the spindles of the muscles.

From experimental studies of spinalised animals it is known that a prolonged facilitation of the flexor reflex can be induced by ectopic C-afferent fibre input arising from damaged or dysfunctional peripheral nerves (Woolf and Wall 1986). This facilitation appears to be due to changes in interneurones involved in reflex pathways, rather than in the α-motor neurones themselves (Cook et al 1986). If the same phenomenon occurs in humans following nerve damage, it is known that spinal interneurons have divergent connections (Gordon 1991) and their activation could explain the more widespread EMG responses to myotatic reflexes elicited in the painful arms of three of the patients.

The Ia afferents are known to exert a disynaptic inhibitory action on motor neurons of antagonistic muscles via Ia inhibitory interneurons (Gordon 1991). The Ia inhibitory neuron receives both excitatory and inhibitory signals from all of the major descending pathways (Gordon 1991). Simultaneous EMG activity recorded in an agonist-antagonist muscle pair with overflow of contraction into remote muscles when myotatic reflexes were elicited in the painful arms of Patients 1, 3 and 4, is reminiscent of the pattern found in disorders of reciprocal inhibition (Rothwell and Obeso 1987). However, as these subjects did not exhibit clinical features of dystonia, the presence of such a disorder seems unlikely.

Microneurographic recordings, which are yet to be confirmed, suggest that fusimotor drive exists in humans at rest (Ribot-Ciscar et al 1992). Animal studies have shown that following experimentally-induced peripheral nerve injury, a small proportion of neurons within the dorsal horn display abnormal responses such as prolonged afterdischarges to very brief stimuli, and ongoing spontaneous activity (Laird and Bennett 1993). This abnormal activity could positively influence fusimotor neurons, leading to an increased fusimotor drive and consequent sensitisation of spindles (ie positive *gamma bias*). The muscle spindle afferents within the dorsal root supplying the motor neurons monosynaptically may spread collaterals over several segments (Rethelyi and Szentágothai 1973). This arrangement makes it likely that an afferent from one hyperexcitable spindle could influence motor neurons in several segments of the cord.

As the intrafusal fibres of muscle spindles are known to have a sympathetic innervation, it has been postulated that tremor sometimes observed in the syndrome known as reflex sympathetic dystrophy (RSD) is an enhanced physiological tremor resulting from increased sympathetic outflow sensitising muscle spindles (Deuschl 1991). However, this explanation is highly contentious as increased sympathetic outflow has not been demonstrated in microneurographic studies performed on patients with RSD (Torebjörk 1990).

Palpation of nerve trunks

The anatomical location of the painful responses to gentle palpation of the arms of these patients suggests that the nerve trunks, and not the adjacent muscles, are sites of mechanical allodynia induced by the proximal primary cervical radicular pathology.

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In this context, the phenomena of nerve trunk pain and peripheral neural secondary hyperalgesia appear to be sensory correlates of central sensitisation. Little is known of the segmental innervation of the connective tissues of peripheral nerve trunks but from this study it appears that the major nerve trunks of the upper limb are innervated multisegmentally.

The widespread and multi-segmental EMG activity in response to palpation of some of the putatively allodynic nerve trunks, and the similar pattern of response when myotatic reflexes were elicited on the painful side, do not have the characteristics of simple flexion reflexes. Rather they appear to be motor correlates of central sensitisation. In the case of nerve trunk palpation, it is possible that they were voluntarily produced. However a more likely explanation is that the central terminals of nerve trunk mechanoreceptors within the dorsal horn have established connections with hyperexcitable α-motor neurons, probably via interneurones (Gordon 1991), or that novel presynaptic connections (cross-excitation) have formed between these central terminals and Ia afferents (Devor 1991).

Palpation of muscles

Increased insertional activity on needle EMG examination was reported within the C6 myotome of Patient 1. This type of activity was thought by Elliott (1944b) to indicate muscle spasm but is now known to reflect a hyperirritable state of muscle membranes following denervation (Johnson 1988). The absence of mechanical allodynia in the muscle bellies adjacent to the allodynic radial nerve trunk in Patient 1, together with the absence of EMG activity accompanying their palpation, are findings which affirm the opinion of Taverner (1954) that muscle spasm (spontaneous motor activity) or irritability are not secondary causes of pain in patients with nerve root irritation.

Study limitations

This study had several technical limitations. When palpation is used as a stimulus, neither the stimulus nor the latency to onset of the responses can be accurately determined, making it impossible to distinguish voluntary from involuntary reflex muscle activity. The same criticism applies to the use in this study of the myotatic reflex as a stimulus. In order to measure the latency to onset of the muscle response, and possibly to be able to make this distinction, it would be necessary to use a stimulus sensitive tendon hammer.

Another limitation of the study is that no attempt was made to standardise the intensity of the palpatory stimuli, for example by using pressure algometry. However, the ability of an experienced examiner to accurately palpate deep structures such as nerve trunks was a central component in the study design, and this accuracy may not have been achievable using a mechanical device.

Finally, the absence of any attempt to quantify evoked EMG activity is another of the study's limitations. It was considered that any activity-related pain in the patients could prevent them from achieving maximal contraction of the muscles sampled for EMG activity, making any quantification of EMG activity extremely difficult to interpret.

Conclusion

The significant findings of this study of the painful upper limbs of patients with cervical radiculopathy are:
(i) mechanical allodynia of peripheral nerve trunks; (ii) widespread EMG activity in response to palpation of allodynic nerve trunks; and
(iii) widespread EMG activity in response to elicitation of myotatic reflexes. If these findings are confirmed by others, they appear to be important sensory and motor correlates of spinal hyperexcitability (central sensitisation).

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